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MIGRATIONS AND GEOGRAPHIC DISTRIBUTION OF PINK SHRIMP, *PENAEUS DUORARUM*, OF THE TORTUGAS AND SANIBEL GROUNDS, FLORIDA¹

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ABSTRACT

Pink shrimp, *Penaeus duorarum*, frequent the estuarine waters of south Florida as juveniles. As adults, they support valuable fisheries on the offshore Tortugas and Sanibel trawling grounds in the Gulf of Mexico. To study the Tortugas and Sanibel shrimp stocks as biological units, 15 mark-recovery experiments in which biological stains were the marking agents were made. These experiments (1) indicated timing and direction of shrimp migrations; (2) delineated estuarine nursery grounds; and (3) outlined geographic ranges of Tortugas and Sanibel shrimp stocks.

Prior to migrating offshore, the length of time spent by juvenile pink shrimp in the nursery areas varies from about 2 to at least 6 months. In migrating from nursery areas, some shrimp travel at least 150 miles (nautical) before recovery on the offshore grounds. Although migration routes are broad, shrimp emanating from particular sections of the nursery grounds demonstrate distinct distributional patterns on the offshore grounds.

The migrations and geographic distribution of pink shrimp, *Penaeus duorarum*, supporting commercial shrimp fisheries on the Tortugas and Sanibel grounds, have not been described previously. These two fisheries, located in the Gulf of Mexico off the southwest coast of Florida, provide a total shrimp catch of about 18 million pounds (heads on) annually. Knowledge of pink shrimp movement and distribution both on and off the grounds will contribute to a more thorough

The nursery grounds of the Tortugas shrimp stocks include Florida Bay and estuaries extending at least as far north as Indian Key on the southwest coast of Florida. The nursery grounds of the Sanibel shrimp stocks are confined to the southwest coast of Florida and include estuaries extending at least from Indian Key north to Pine Island Sound.

The geographic ranges of the Tortugas and Sanibel pink shrimp stocks overlap in the nursery areas near Indian Key and in the offshore water between the two trawling grounds. Apparently, Tortugas shrimp do not migrate to the Sanibel grounds and migration from the Sanibel to the Tortugas grounds is minimal. The geographic distributions depicted may constitute minimums for two reasons: First, the absence of fishing effort in certain contiguous areas prevented observations which could extend the known distribution. Second, larval and postlarval pink shrimp may migrate to or from areas beyond the ranges frequented by Tortugas and Sanibel shrimp as juveniles and adults.

understanding of this animal's biology and serve as a basis for management of this resource.

The catch on the Tortugas and Sanibel grounds consists primarily of maturing and adult pink shrimp. This species has a life history similar to other members of the genus *Penaeus*. As adults, the female pink shrimp extrude eggs in offshore waters. After hatching, the young shrimp pass through larval and into postlarval stages as they move toward the coast. Coastal shallows and estuaries, utilized as nursery grounds, furnish an ecological environment considered necessary for these shrimp during the early stages of their development. The shrimp gradually move off-

¹ Contribution No. 193. Bureau of Commercial Fisheries Biological Laboratory, Galveston, Tex.

NOTE.—Approved for publication Sept. 29, 1964.

shore while maturing. The larger individuals eventually occupy the deeper waters (Iversen, Jones, and Idyll, 1960).

To study the Tortugas and Sanibel pink shrimp stocks as biological units, we must define the areas supporting these populations (or this population). This definition requires delineation of the shallows and estuaries that sustain young pink shrimp before they migrate to the Tortugas or Sanibel grounds, as well as the deeper, offshore waters frequented by the adult shrimp.

The extensive shallow waters surrounding and penetrating the southern portion of peninsular Florida and the adjoining Florida Keys support an abundance of juvenile pink shrimp, some of which are captured and sold as bait (fig. 1). Florida Bay, lying between the southern tip of Florida and the Florida Keys, is considered an important nursery area supplying pink shrimp to the Tortugas grounds (Iversen and Idyll, 1960). These nursery grounds may extend southwestward into the grassy shallows west of Marquesas Keys (Ingle, Eldred, Jones, and Hutton, 1959). Broad (1950) notes that "ample nursery grounds are to be found on the Florida west coast between Cape Sable and Cape Romano where the coastline is broken by numerous bays, creeks and rivers."

Maturing and adult pink shrimp are found in most offshore waters adjacent to south Florida, sometimes in depths of 60 fathoms² (Bureau of Commercial Fisheries, 1961 and 1962). On the

Florida shelf, however, much of the bottom is too rough for conventional trawling gear. South of lat. 27°00' N., the region under discussion, large pink shrimp are generally taken commercially only on the Sanibel, Tortugas, and Hawk Channel grounds where relatively smooth bottom can be found. Pink shrimp are fished commercially to a maximum depth of about 33 fathoms. The greater depths of the Straits of Florida, to the south and east of the Tortugas grounds, and the Gulf of Mexico, to the west, may serve as barriers to the migration of juvenile and adult pink shrimp.

In 1958, a total of 1,157 pink shrimp were tagged with Petersen disks and released near Flamingo in Everglades National Park. From this group, 1 tagged shrimp was recovered on the Tortugas grounds (Iversen and Idyll, 1960). Prior to this recovery no direct evidence linked small pink shrimp from south Florida estuaries to those larger shrimp supporting offshore fisheries. In addition, the relationship of pink shrimp occurring on the Hawk Channel and Sanibel grounds to the Tortugas pink shrimp was unknown. In 1958, the Bureau of Commercial Fisheries began a series of mark-recovery experiments in the waters of south Florida. One result of these experiments has been to demonstrate that certain shallow coastal waters are important contributors of recruits to the Tortugas and Sanibel shrimp fisheries. These experiments also outlined much of the range of the Tortugas and Sanibel pink shrimp stocks.

In studying pink shrimp, we were also concerned with the incidence of similar species that might be mistaken for pink shrimp. Two species closely related to pink shrimp have been reported from the waters of south Florida. These are *Penaeus brasiliensis* (Eldred, 1960) and *Penaeus aztecus* (Burkenroad, 1939; Tabb and Manning, 1961; Bureau of Commercial Fisheries, 1961). In Biscayne Bay and Hawk Channel, a relatively small number of *P. brasiliensis* were marked and released with *P. duorarum*. *P. brasiliensis* has not been noted from the Tortugas or Sanibel grounds despite examination of many shrimp from these areas. Two specimens of *P. aztecus* have been recorded from the northwest portion of the Sanibel grounds, but none from the Tortugas grounds.

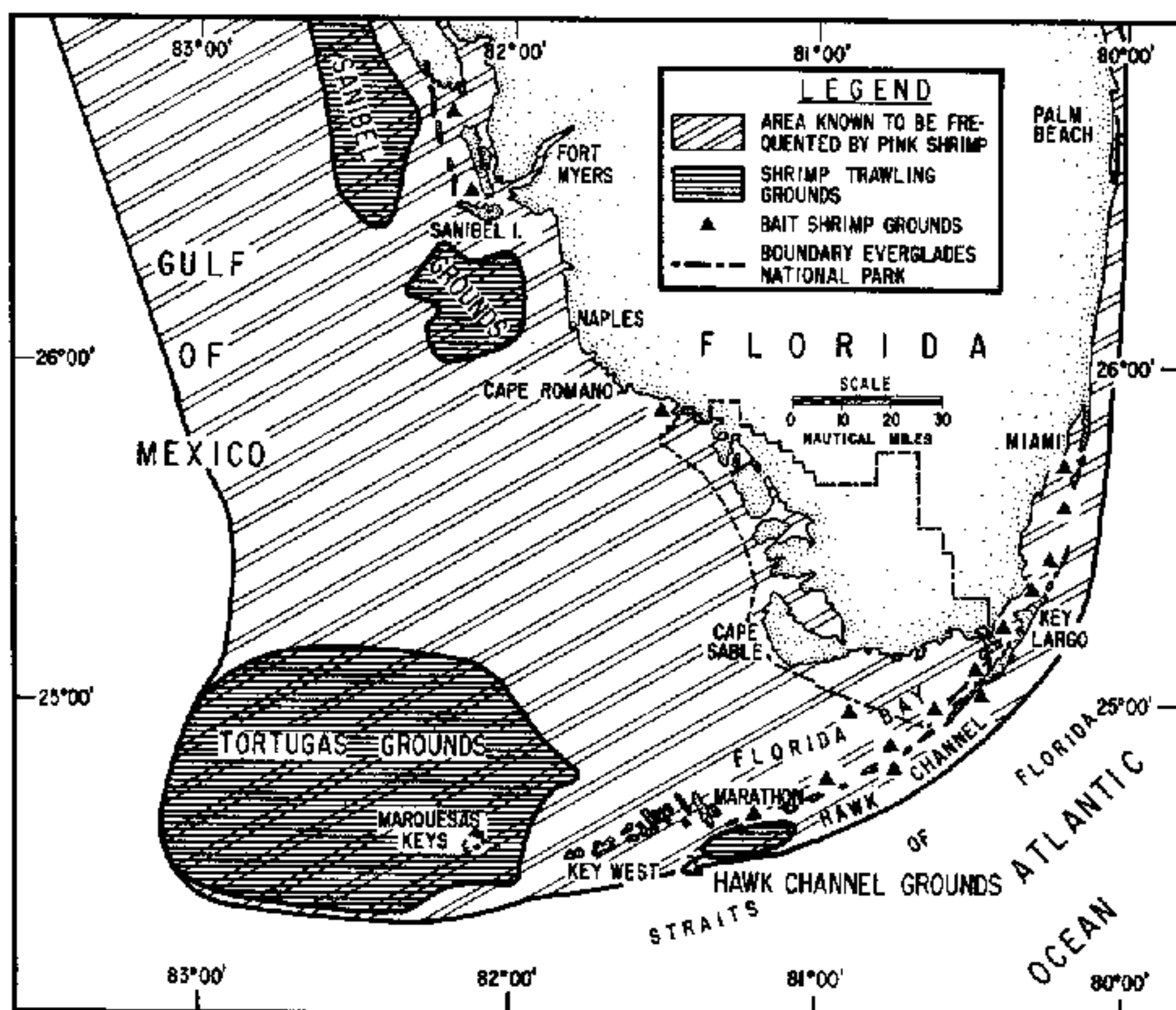


FIGURE 1.—Distribution of pink shrimp in the waters of south Florida.

² Off the western edge of the Great Bahama Bank pink shrimp have been found in depths up to 200 fathoms (Bureau of Commercial Fisheries, 1961).

PROCEDURE

Design of Experiments

The experimental plan was based on the assumption that nursery grounds that furnish recruits to Tortugas and Sanibel pink shrimp populations are located in the estuaries and shallow marine waters of south Florida. To delineate these nursery areas and relate them to specific offshore shrimp-ing grounds, young shrimp at selected coastal sites were captured, marked, and released near the point of original capture. Recovery of these marked shrimp on the Tortugas or Sanibel grounds established the affiliation of shrimp from a nursery area to those on the offshore grounds.

Inshore release sites were selected geographically near centers of juvenile shrimp abundance. At several of the selected locations, juvenile pink shrimp are plentiful only seasonally. Therefore, to obtain sufficient shrimp for marking, timing of inshore releases necessarily coincided with these estuarine peaks of abundance. Proceeding with marked shrimp releases according to these criteria, we established the affiliation of shrimp from shallow water areas along an extensive expanse of coastline to the offshore grounds.

Three offshore mark-recovery experiments, designed primarily to determine growth and mortality rates, also furnished information concerning migration and distribution of the larger pink shrimp.

Marked shrimp, which form the basis of this report, were stain-marked by injection of biological stains (Menzel, 1955; Dawson, 1957; Costello, 1964).

Recovery of Stained Shrimp

Shrimp fishermen and packers were informed of the purpose of mark-recovery experiments prior to each release of stain-marked shrimp. Preserved stain-marked shrimp in glass vials were displayed and posters describing stain-marked shrimp were placed in shrimp packing plants. For each recovery, together with the position, date and depth of recapture, rewards of from \$1 to \$5 were offered at various stages of the program.

Except for four recoveries made by Bureau of Commercial Fisheries vessels, all 2,201 of the marked shrimp recoveries which form the basis of this report were made by commercial fishing vessels. Inshore recoveries were made by bait

shrimp fishermen in Biscayne Bay, Barnes Sound, and Florida Bay, and near Indian Key.

Stain-marked shrimp released offshore in or near areas where shrimp trawlers were active were caught and returned for reward payments in surprising numbers. Two groups released on the Tortugas grounds yielded 1,227 recoveries—21.1 percent of the first group released and 33.3 percent of the second group released. On Sanibel, 563 marked shrimp were recovered from a release of 2,496—a 22.5 percent recovery.

Inshore or estuarine releases were usually in localities remote from commercial fishing operations. This is reflected in recovery rates which averaged less than 1 percent of the numbers released.

Recovery rates are affected by factors such as the effective number of marked animals released—the number returned safely and in good condition to the environment from which captured. Also affecting recovery rates are direction of migration, location and amount of fishing effort, and awareness and interest of industry personnel in a position to recover marked shrimp. Some or all of these factors varied during the course of these experiments, and they have been considered in evaluating the data.

MIGRATIONS

Release and Recovery Sites

Table 1 summarizes pink shrimp mark-recovery experiments in south Florida waters from 1958 to 1963. Release sites are numbered in chronological order.

Figure 2 depicts the numbered release sites and general area of recovery of stain-marked shrimp. Arrows joining release and recovery sites do not necessarily indicate routes of migration.

On the southwest coast of Florida, marked juvenile pink shrimp released in large numbers in Pine Island Sound (10) migrated to the south and northwest portions of the Sanibel grounds but not to the Tortugas grounds. A release southeast of Sanibel, at Indian Key (14), resulted in recoveries near Indian Key and on both the Sanibel and Tortugas grounds. On the southwest coast of Florida and in Florida Bay, marked juvenile pink shrimp released near Shark River (6), Flamingo (2), Bottle Key (9), and Peterson Keys (3) were recovered in the Tortugas shrimp fishery. Several shrimp from Bottle Key were also caught in

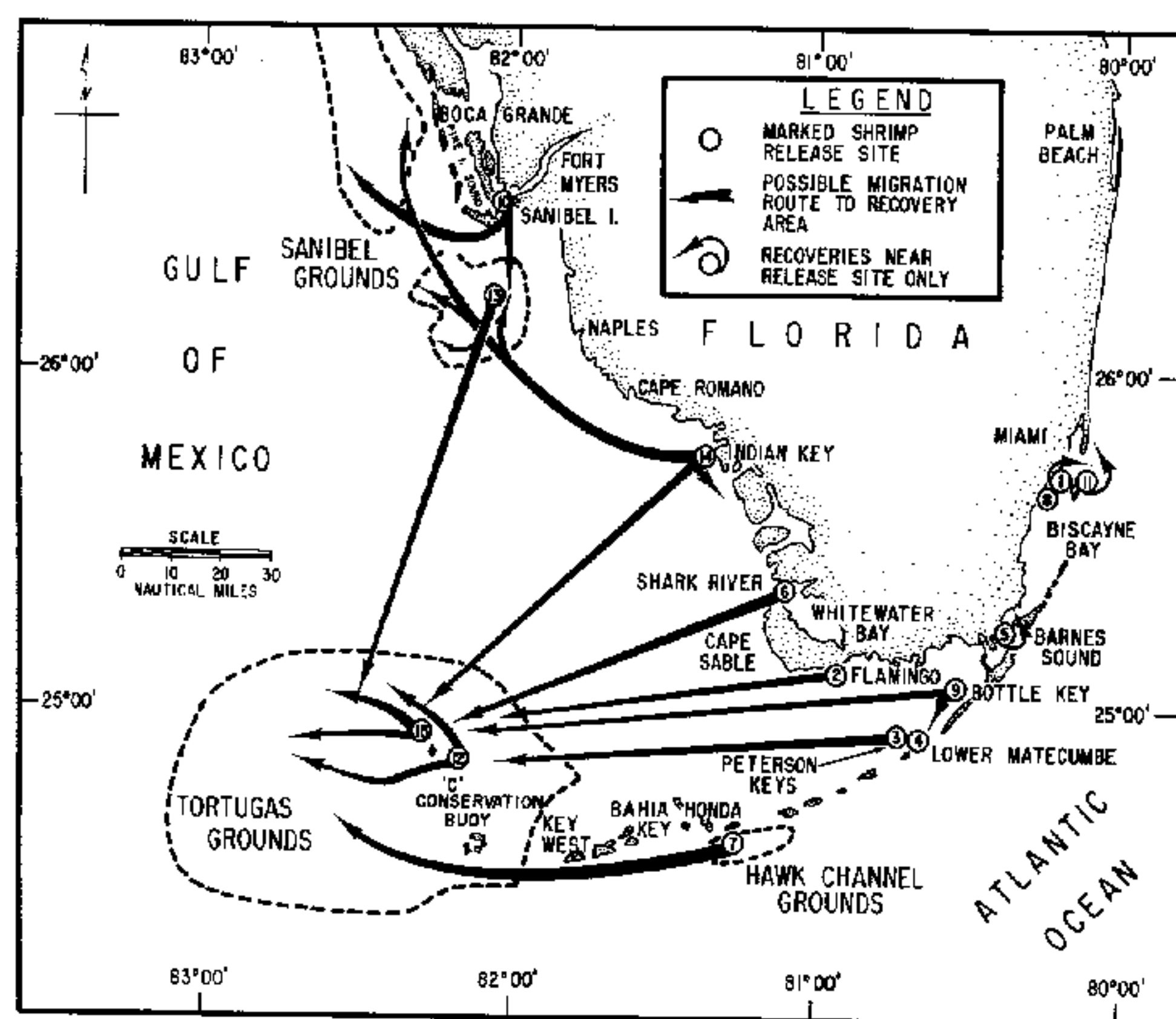


FIGURE 2.—Release-recovery sites of marked pink shrimp in the waters of south Florida, 1958–63.

Florida Bay near and south of their release site, and one was recovered about 6 miles³ north of

³Nautical miles are used in this report.

the northern border of the Tortugas grounds. A few shrimp released at Bottle Key migrated at least 150 miles to the western portion of the Tortugas grounds.

On the southeast coast of Florida, young shrimp released in Biscayne Bay (1 and 11) and Barnes Sound (5) were recovered only near their respective release sites. No recoveries were reported from one release in Biscayne Bay (8) or from a small release at Lower Matecumbe Key (4), which borders eastern Florida Bay.

Migrations of adult shrimp were determined by releases in the deeper, offshore waters. Although a release of maturing shrimp on the south Sanibel grounds (13) resulted in 561 recoveries in the south Sanibel fishery, only two shrimp migrated to the Tortugas grounds. Marked shrimp released on two separate occasions on the Tortugas grounds near 'C' conservation buoy (12 and 15) apparently remained on or near the Tortugas grounds. The net movement of recovered individuals released on the Tortugas grounds was northwesterly into deeper water. Similar movement has been reported for tagged pink shrimp

TABLE 1.—Summary of pink shrimp mark-recovery experiments in south Florida waters, 1958–63

Release site	Site number	Date of release	Released	Area of recovery	Recovered	Period of recovery	Days-out time ¹		
							Minimum	Maximum	Mean ²
Biscayne Bay	1	1958 Apr. 24–May 29	Number 19,358	Biscayne Bay	Number 57	May–July 1958	Number	Number	Number
Flamingo	2	Oct. 24–31	7,264	Tortugas grounds	4	Jan.–Feb. 1959	84	121	(³) 99
Peterson Keys	3	1959 Jan. 29	1,729	Tortugas grounds	11	Mar.–May 1959	46	93	69
Lower Matecumbe Key	4	Mar. 6	1,672		0	No recoveries			
Barnes Sound	5	July 7–16	7,084	Barnes Sound	29	Aug. 1959–Jan. 1960	16	174	73
Shark River	6	Nov. 2–6	16,638	Tortugas grounds	31	Dec. 1959–Mar. 1960	35	126	81
Hawk Channel	7	1960 Feb. 4	6,815	Tortugas grounds	18	Mar.–May 1960	50	160	83
Biscayne Bay	8	Aug. 9	11,000		0	No recoveries			
Bottle Key	9	Nov. 1–4	13,306	Florida Bay	10	Nov. 1960–Jan. 1961	22	80	31
Pine Island Sound	10	Nov. 29–Dec. 15	32,913	Tortugas grounds	50	Jan.–May 1961	72	205	124
				S. Sanibel grounds	149	Jan.–Nov. 1961	36	331	106
				NW. Sanibel grounds	6	Mar.–May 1961	112	160	135
Biscayne Bay	11	1961 Apr. 18	2,775	Biscayne Bay	4	May–June 1961	34	58	51
Tortugas grounds	12	Sept. 20–23	2,091	Tortugas grounds	443	Sept.–Dec. 1961	1	85	28
Sanibel grounds	13	1962 Mar. 19–22	2,496	Sanibel grounds	561	Mar.–Aug. 1962	1	146	33
				Tortugas grounds	2	July 1962	115	115	115
				Indian Key	11	Sept. 1962	7	19	14
Indian Key	14	Aug. 27–Sept. 5	19,860	S. Sanibel grounds	22	Oct. 1962–Apr. 1963	53	229	159
				NW. Sanibel grounds	1	Nov. 1962	89	89	89
Tortugas grounds	15	Dec. 11–15	2,350	Tortugas grounds	8	Oct. 1962–Mar. 1963	40	185	128
				Tortugas grounds	784	Dec. 1962–Mar. 1963	1	106	21
Total			147,351		2,201				

¹ Calculated from the mean release date.

² Calculated from all recoveries.

³ Widespread of release dates at site number 1 negates value of "days-out time" data.

released and recovered on the Tortugas grounds (Iversen and Jones, 1961). Another offshore release of stain-marked shrimp in Hawk Channel (7), south of Bahia Honda Key, yielded recoveries on the Tortugas grounds.

Areal Distribution

In figure 2 lines connecting release and recovery sites suggest possible migration routes traversed by pink shrimp en route to the Tortugas or Sanibel grounds. Actual routes of migration are not known because of the few recoveries in intervening areas which receive limited fishing effort. One exception pertains to the inshore leg of the route followed by shrimp released near Bottle Key as they moved toward the Tortugas grounds. From this group, a bait shrimp fisherman recovered 10 marked shrimp in Florida Bay 22 to 80 days after release. Of these 10, 7 were found near the release site, and 3 had moved southwest of Bottle Key toward a pass breaching the Florida Keys. Higman (1952) reported large catches of shrimp at such passes on night tides flowing from Florida Bay to the Atlantic Ocean. Undoubtedly, many shrimp from Florida Bay move into Hawk Channel, and we have now established that shrimp from the Hawk Channel grounds south of Bahia Honda Key migrate to the Tortugas grounds. Such movement was suggested by Costello and Allen (1960).

The distribution of recoveries from individual releases shows that migration routes may be broad and that shrimp disperse considerably while migrating. For example, shrimp released at Indian Key have been recovered at points as far as 125 miles apart. When there is a protracted departure time from a release site, such as occurred at Bottle Key (table 1), separate elements of the marked group may be subjected to a diverse environment (temperature, salinity, tides, currents) that could affect the direction of migration.

On the Tortugas grounds, the size of pink shrimp increases with the depth (Iversen, Jones, and Idyll, 1960). In general, mark-recovery experiments also indicate that pink shrimp move into deeper water as they increase in size. Thus, from examining the depth contours, we would expect that the majority of recruits enter the Tortugas and Sanibel grounds from the shallower waters northeast, east, or southeast of the grounds. On the Tortugas grounds the recovery patterns of marked

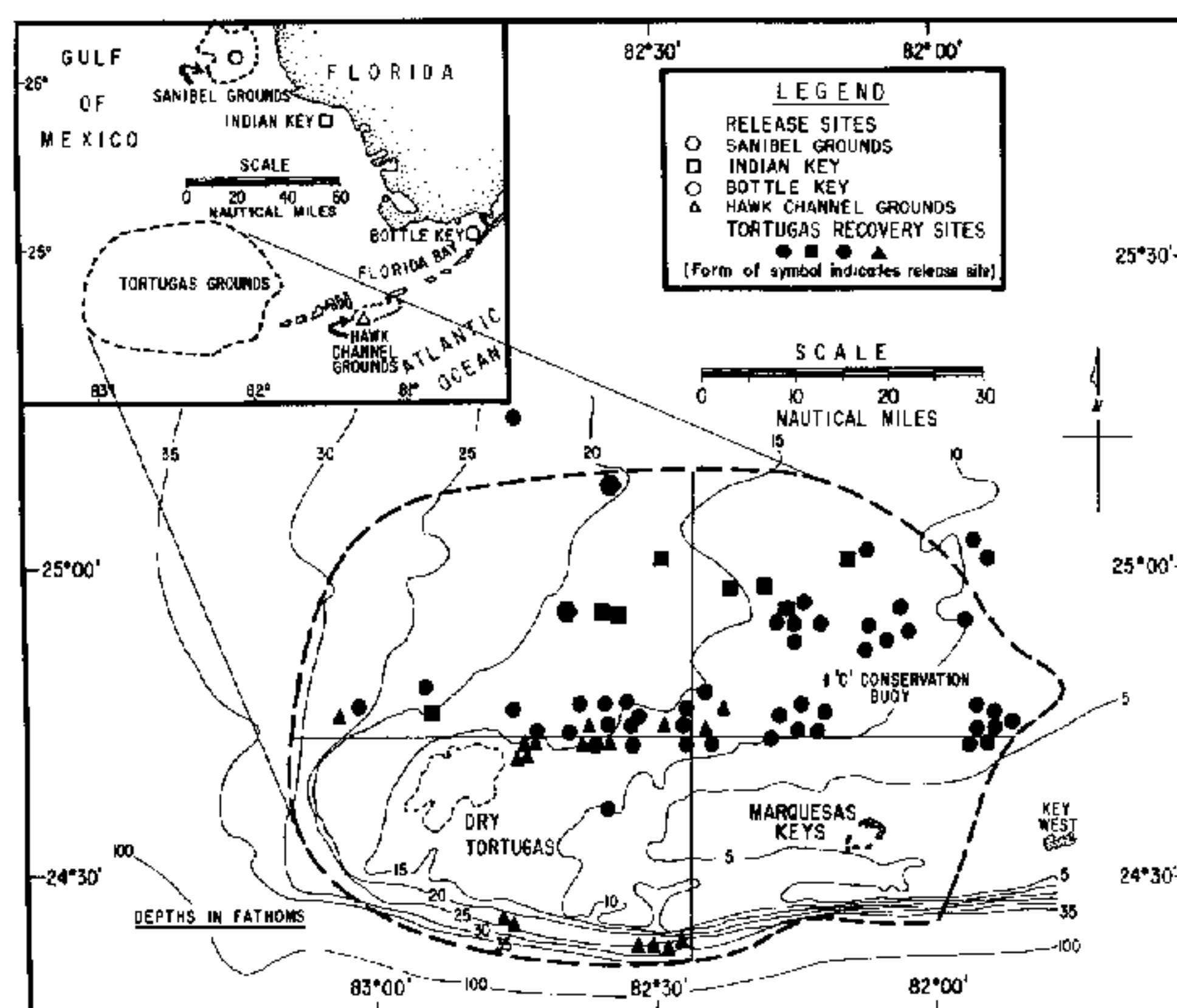


FIGURE 3.—Distribution of recoveries of pink shrimp on the Tortugas grounds from four release sites.

shrimp from a common release area suggest the directions from which the shrimp enter the grounds. Reference is made to figure 3, which illustrates the recovery positions on the Tortugas grounds of shrimp liberated at four release sites. Because of varied fishing effort, the actual distributional pattern of marked individuals on the grounds may differ somewhat from that suggested by the recoveries. The greatest concentration of fishing pressure occurs in the northeast quadrant of the grounds followed, in descending order, by the northwest, southwest, and southeast quadrants. Fishing pressure in the southeast quadrant is minimal and probably few recoveries should be expected from there. Bearing these qualifications in mind and by inspecting figures 2 and 3, we made the following observations:

1. Recoveries of shrimp migrating from the Sanibel grounds (13) were confined to the northwest quadrant of the Tortugas grounds, suggesting entrance from the north.
2. Recoveries of shrimp migrating from Indian Key (14) were distributed within the northwest and northeast quadrants of the Tortugas grounds, indicating entrance from the north and northeast.
3. Recovery positions of shrimp migrating from Bottle Key (9) were concentrated in the northeastern and west central portions of the grounds. This recovery pattern may be distorted by the limited fishing effort in the southeast quadrant. Thus, indications are that Bottle

Key shrimp entered the Tortugas grounds from the east, and, perhaps, northeast and southeast.

4. Shrimp that migrated from Hawk Channel (7) were concentrated along the southern border and in the west central section of the Tortugas grounds. Once again, the distributional pattern may be distorted by limited fishing effort in the southeast quadrant. It appears, however, that Hawk Channel shrimp entered the grounds from the southeast.

On the south Sanibel grounds, distribution of the first 23 recoveries of marked shrimp released in Pine Island Sound indicates that these shrimp entered the grounds from the shallower waters to the northeast and east (fig. 4). A comparison of the distributional pattern of the last 23 recoveries with that of the first 23 indicates the general trend of movement was into deeper water, or southwestward on the south Sanibel grounds.

TIME DISTRIBUTION

The period of time expended by pink shrimp (1) on nursery grounds, (2) while traversing migration routes, and (3) on the offshore grounds can be approximated in some cases from the number of days elapsing between release and recovery of marked shrimp, or "days out time" (table 1). Recovery frequencies for half-month periods on

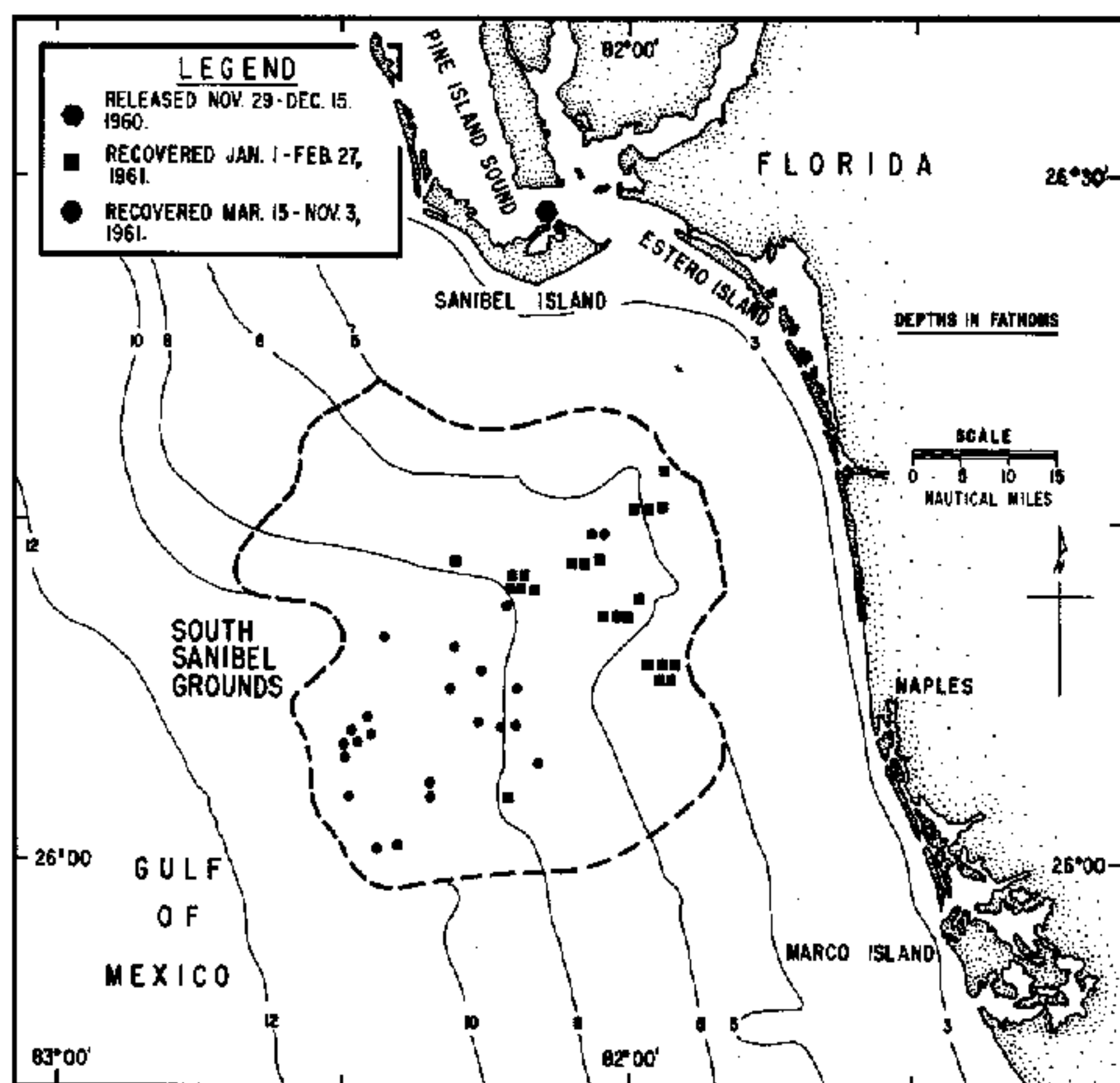


FIGURE 4.—Distribution of recoveries of pink shrimp on the south Sanibel grounds from releases in Pine Island Sound.

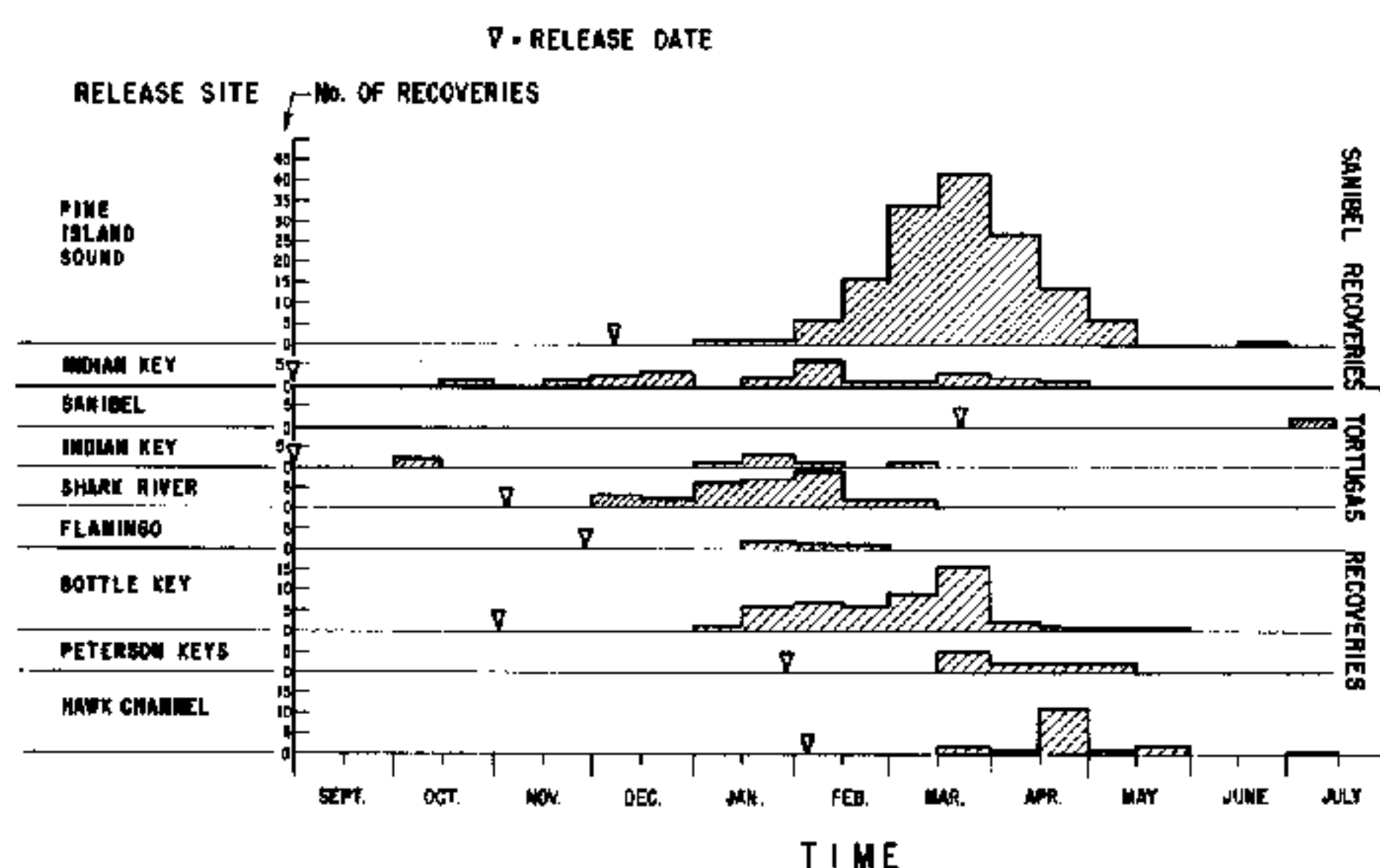


FIGURE 5.—Time-frequency distribution of marked shrimp recoveries on the Tortugas and Sanibel grounds by one-half-month periods.

the Tortugas and Sanibel grounds (fig. 5) indicate periods of availability of marked shrimp from various release sites. Caution in interpreting these data is necessary since not all shrimp of a marked group depart the release areas at the the same time, are recovered immediately upon reaching the offshore grounds, or are recovered in proportion to their relative abundance.

A few pink shrimp that were marked and released in Barnes Sound (5) remained in the Sound for at least 174 days. Following the pink shrimp age-size relation given by Kutkuhn,⁴ we estimated the smallest shrimp released, 16.0 mm. carapace length (75.0 mm. total length), to be about 60 days old. If 21–28 days are allowed for larval and early postlarval development prior to entrance into the nursery grounds, then it appears that under certain conditions more than 6 months of life may be spent in the estuaries. Conversely, time spent in the estuaries may be relatively brief. Only 35 days after the Shark River release (6), one marked male, 20.2 mm. carapace length (94.8 mm. total length), was recovered on the Tortugas grounds. Estimating this shrimp's age as 79 days and subtracting pre-estuarine entrance time, we found it apparently spent less than 2 months in the estuarine environment. The occurrence of pink shrimp less than 20.0 mm. carapace length (92.5 mm. total length) on the Tortugas grounds may indicate that some individuals spent little or no time on the more distant estuarine nursery grounds.

⁴ Kutkuhn, Joseph H., Dynamics of a penaeid shrimp population and management implications, p. 313, loc. cit.

Marked shrimp from the Bottle Key release (9), made in November 1960, were recovered in Florida Bay up to 80 days after release. One marked shrimp was recovered in the Bay after two other Bottle Key shrimp had already been caught on the Tortugas grounds. These recoveries show clearly that not all members of a given group of shrimp depart the estuaries at the same time. Bottle Key shrimp were recovered on the Tortugas grounds from January through May 1961 (fig. 5). The majority, however, were taken between January 16 and March 31, indicating that most of the marked Bottle Key shrimp that reached the Tortugas grounds were available for recapture within 75 to 149 days after release. The straight line distance between Bottle Key and 'C' conservation buoy, located near the center of fishing effort on the Tortugas grounds, is about 100 miles. Stained shrimp released in September 1961 (12) and December 1962 (15), near 'C' buoy on the Tortugas grounds, were recovered up to 85 and 106 days after release, respectively. During these periods, many had moved west or northwest into deeper water, some as far as 35 miles. Although several shrimp from release site 15 were taken just south of the northern border of the Tortugas grounds, none was recovered off the Tortugas grounds (fig. 6).

Marked shrimp released in Pine Island Sound (10) in November and December 1960, were re-

covered on the Sanibel grounds from January through November 1961. The center of the south Sanibel grounds is about 22 miles from the release site. The greatest numbers are recovered between February 1 and May 15. Part of the increase during this period, however, may be a reflection of increased fishing effort. One shrimp was recovered on the Sanibel grounds about 11 months after release. Since the smallest shrimp released was estimated to have been at least 1 month old, the recovered shrimp must have been at least a year old.

Marked pink shrimp released on the south Sanibel grounds (13) in March 1962 were caught there up to 146 days after release. The recovery positions indicated gradual movement into deeper water to the west and southwest. After 115 days two marked shrimp were caught on the northwestern Tortugas grounds, about 80 miles distant.

GEOGRAPHIC RANGE OF THE TORTUGAS AND SANIBEL PINK SHRIMP

The range and relationship of pink shrimp stocks of the Tortugas and Sanibel grounds were demonstrated by mark-recovery experiments. The Tortugas stocks of pink shrimp are defined as those pink shrimp that are available for capture on the Tortugas shrimp trawling grounds during some portion of their life. The Sanibel stocks may be similarly defined by appropriate word substitution. The sources of pink shrimp eggs and larvae that perpetuate these fisheries have not been positively established. Much of the area frequented by Tortugas (or Sanibel) pink shrimp as juveniles and adults, however, can be determined by inspection of marked shrimp release-recovery information (fig. 2 and table 1). Figure 7 is provisional and probably depicts only the minimum ranges of the Tortugas and Sanibel pink shrimp stocks.

Tortugas Stocks

The Tortugas trawling grounds, located northwest, west, and southwest of Key West, have a maximum depth of about 33 fathoms. The "boundary" is rather indefinite and encloses about 3,100 square miles. In much of the area trawling is restricted by rough bottom or extreme shallowness.

North, northeast, and east of the Tortugas grounds, the Tortugas stocks of pink shrimp

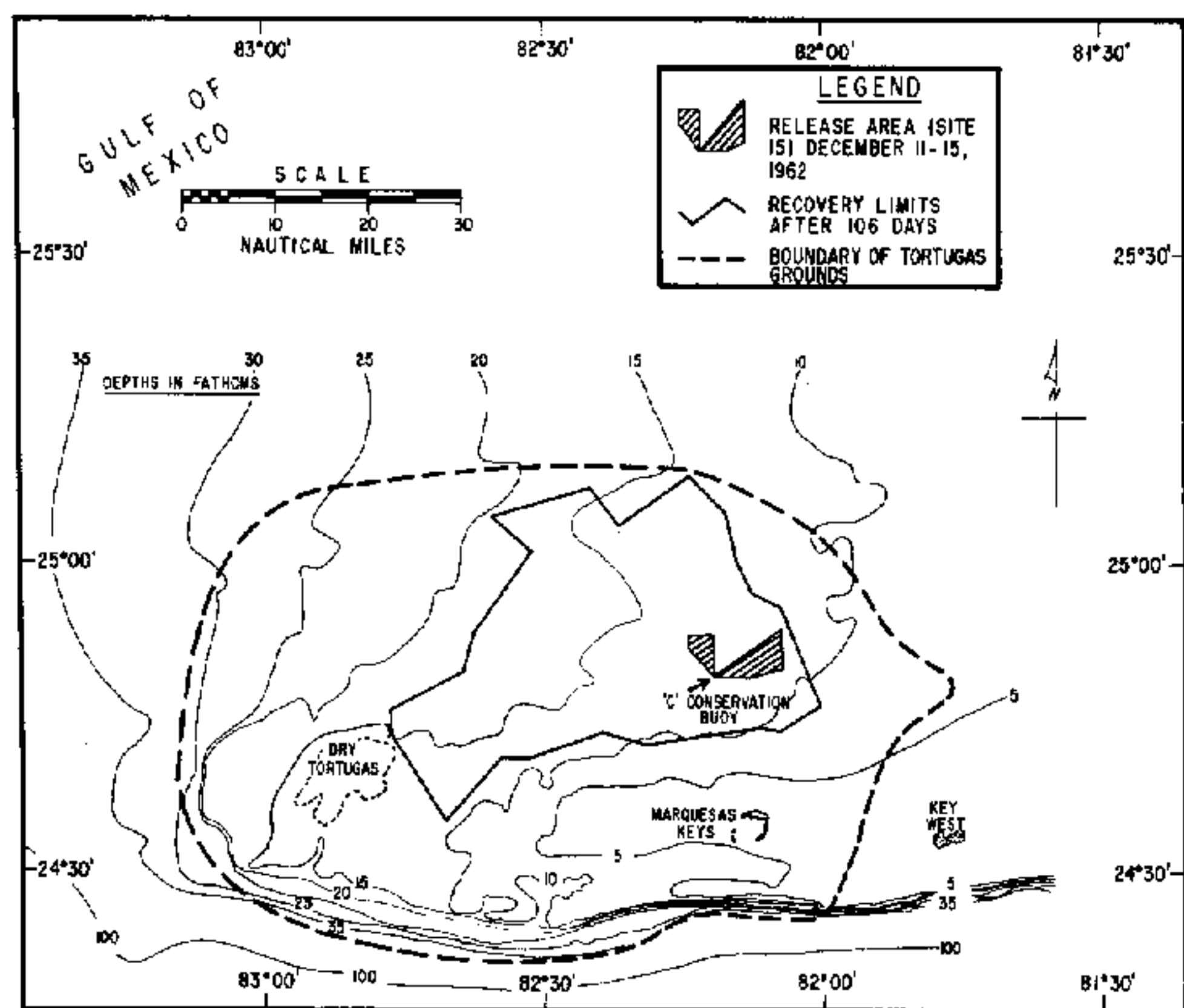


FIGURE 6.—Dispersal of marked pink shrimp on the Tortugas grounds, December 1962 through March 1963.

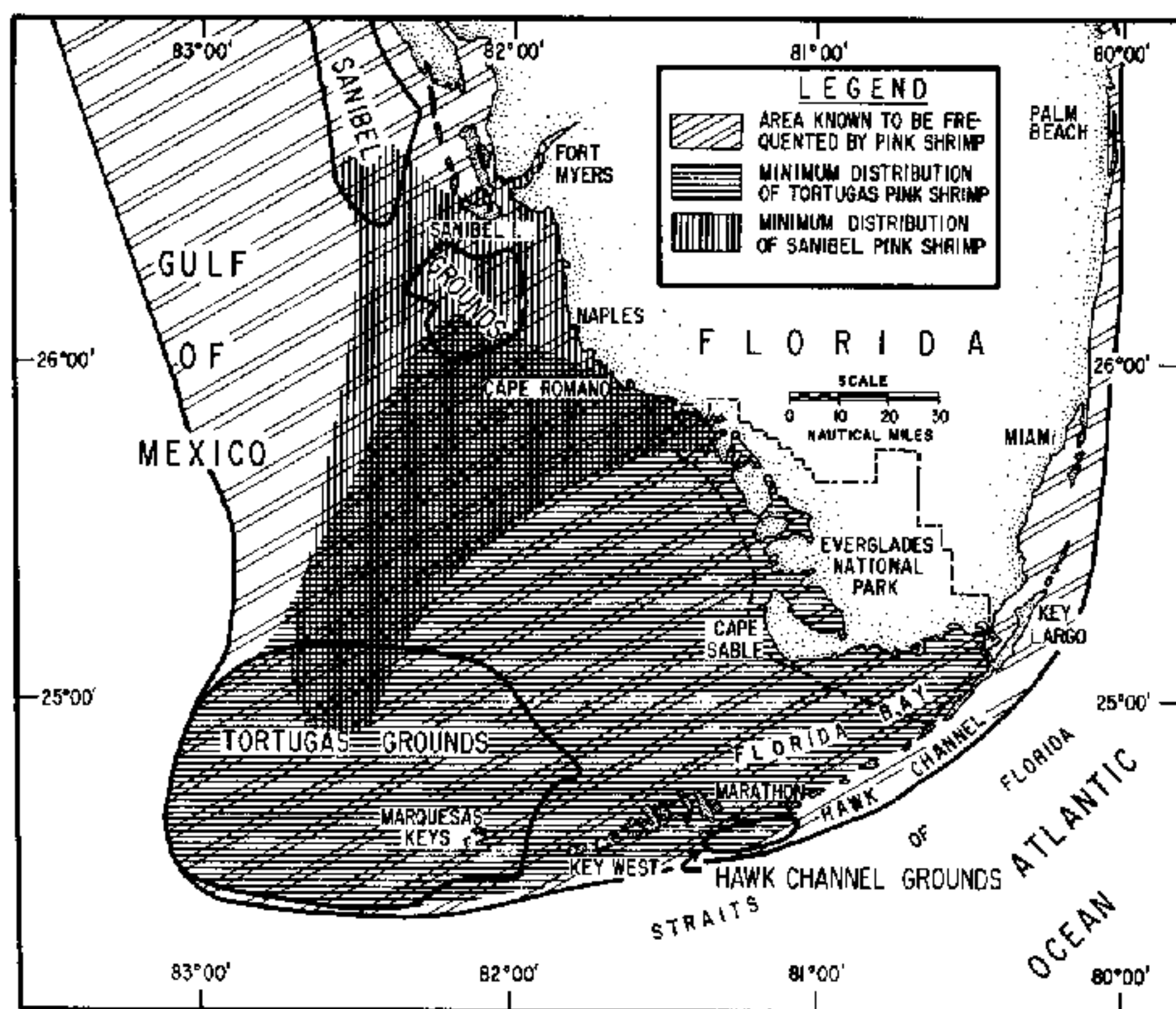


FIGURE 7.—Provisional ranges of Tortugas and south Sanibel pink shrimp stocks.

frequent an area extending at least to release sites 13, 14, 6, 2, 9, 3, and 7 (fig. 2). From the south section of the Sanibel grounds (13), two marked shrimp moved southward to the northwest portion of the Tortugas trawling area, establishing a degree of affiliation between these two fisheries. Because many juvenile shrimp released in Pine Island Sound (10) migrated to the Sanibel shrimp fishery, the relationship of Pine Island Sound shrimp to the Tortugas stocks is also indicated. A total of 35,409 marked shrimp released on Sanibel and in Pine Island Sound, however, yielded 716 recoveries in the Sanibel fishery and only two recoveries to the south, on the Tortugas grounds. Therefore, contribution of shrimp from these two northern sites to the Tortugas fishery must be considered minimal.

Indian Key (14) is about 55 miles southeast of Pine Island Sound. Juvenile pink shrimp from Indian Key are definitely affiliated with the Tortugas stocks, although almost three times as many marked shrimp released at Indian Key were recovered on the Sanibel grounds as on the Tortugas grounds. Analysis of recoveries from release sites 10, 14, and 6 suggests that the northward distribution of Tortugas pink shrimp along the Florida west coast ends north of Indian Key.

Southward from Indian Key to Shark River (6), Flamingo (2), and the Whitewater Bay-Florida Bay complex, we found the northeasterly penetration of the Tortugas pink shrimp stocks restricted

by the land mass of the Florida peninsula, not by the coastline. For the Whitewater Bay drainage area, Tabb, Dubrow, and Jones (1962) presented evidence linking juvenile shrimp from estuaries upstream (inland) to the Tortugas population and to coastal release sites proven to be Tortugas affiliated.

The Tortugas pink shrimp recruitment range extends eastward at least to Bottle Key (9) and probably ends at the periphery of northeastern Florida Bay. Evaluation of the results of releases 6, 2, 9, 3, and 7 strongly indicates that all of Florida Bay provides recruits to the Tortugas fishery. Evidence that a separation of stocks may occur between Bottle Key and Barnes Sound (5) is indicated by the fact that considerably more marked shrimp were released in the Tortugas non-contributing areas northeast of Bottle Key than in the adjacent contributing areas to the southwest. A total of 40,217 marked shrimp was released in Biscayne Bay (1, 8, and 11) and Barnes Sound as compared to a total of 15,035 released near Peterson Keys (3) and Bottle Key. Recoveries in Barnes Sound were particularly interesting, because some marked shrimp were recovered near the release site more than 5½ months after release. The Biscayne Bay and Barnes Sound releases, however, occurred in late spring and summer, while the Peterson Keys and Bottle Key releases occurred in late fall and winter. The possibility cannot be discounted that migration patterns and, therefore, stock distribution may vary seasonally. More definitive results might be obtained from releases in both areas during the same season. However, marked shrimp releases at Bottle Key could not be seasonally timed to coincide with the prior release in Barnes Sound because pink shrimp occur in sparse quantities in northeastern Florida Bay during the summer.

The negative results of the Lower Matecumbe Key release (4) can possibly be attributed to a separation of stocks in that area, but are more likely a reflection of the relatively few (1,672) marked individuals released.

In the offshore waters east of the Tortugas grounds, the Tortugas pink shrimp recruitment range extends at least to that part of Hawk Channel (7) south of Bahia Honda Key. However, if shrimp from the Peterson Keys-Bottle Key area are found to use the adjacent Hawk

Channel as a route to the Tortugas grounds (migrations), the known limit of the Tortugas population would be extended northeastward on the Atlantic side of the Keys.

South, southeast, and east of Hawk Channel, pink shrimp have been caught in the Straits of Florida in depths to 60 fathoms (Bureau of Commercial Fisheries, 1961 and 1962). South of the Tortugas trawling grounds, pink shrimp have been taken in depths to 37 fathoms (Springer and Bullis, 1954). At these depths, however, pink shrimp have not been found abundant. The relationship of these "deep water" shrimp to those inhabiting the relatively shallow water of the Tortugas grounds has not been determined.

Sanibel Stocks

The Sanibel grounds comprise two distinct areas of trawlable bottom and are located northwest and south of Sanibel Island. Most trawling is confined to depths of less than 10 fathoms. The southern boundary of the south Sanibel grounds is about 50 miles north of the Tortugas northern boundary (fig. 1). The northwest portion of the Sanibel shrimp grounds represents the southern extremity of a sporadic, undefined pink shrimp fishery which parallels a large portion of the Florida west coast.

Recoveries of marked shrimp reveal that Pine Island Sound serves as a nursery ground for both sections of the Sanibel grounds.

In this discussion the two Sanibel areas will be treated separately since there are indications that the northwest Sanibel grounds may support stocks of pink shrimp differing from those of the south Sanibel grounds. This is suggested by the fact that while 2,496 marked shrimp were released on south Sanibel (13), and 563 recovered there, none was recovered on northwest Sanibel despite moderate fishing effort in the latter area. One marked shrimp, however, from the Indian Key release (14) was recovered in the northwest Sanibel fishery. This shrimp very likely passed through the south Sanibel grounds en route to northwest Sanibel, linking all three areas. These apparently contradictory results may indicate that movement of shrimp from the southeast to northwest Sanibel is seasonal or sporadic. Because no marked shrimp have been released on northwest Sanibel, the relationship of shrimp from this area to shrimp stocks to the south is unknown.

The coastal distribution of shrimp recruited to the south Sanibel fishery extends from at least Pine Island Sound (10) to Indian Key (14). Juvenile shrimp recruited to the south Sanibel fishery probably issue from estuaries between and including these release sites. Since 22 of the marked shrimp released at Indian Key were recovered on the south Sanibel grounds, as compared with 8 on the Tortugas grounds, the southeastern limits of the south Sanibel shrimp population probably lie south of Indian Key but north of Shark River. The latter point is emphasized by the fact that releases of 16,638 marked shrimp at Shark River and 23,971 in Florida Bay have resulted in numerous recoveries on the Tortugas grounds but none on the Sanibel grounds.

The distribution of recoveries from coastal and offshore releases provides good evidence that the Tortugas and Sanibel shrimp stocks overlap in the general area of Indian Key (14) and offshore, between the Tortugas and Sanibel grounds. Two stain-marked shrimp, mentioned previously, migrated from the Sanibel to the Tortugas grounds, apparently crossing the intervening area. The bottom in this area is rough and usually precludes successful trawling with conventional shrimping gear. Despite low fishing effort in the area, two pink shrimp tagged and released on the Tortugas grounds were recovered 11 and 14 miles north of the present northern border of the Tortugas grounds (Iversen and Jones, 1961). In addition, one stain-marked shrimp from the Bottle Key release was recovered 6 miles north of the Tortugas border (fig. 3). There is no evidence, however, of migration from the Tortugas to the Sanibel grounds. Of 4,441 stain-marked shrimp released on the Tortugas grounds, none was recovered on or near Sanibel grounds. Because the movement of pink shrimp is generally into deeper water, migration from the Tortugas grounds to the shallower Sanibel grounds seems unlikely.

SUMMARY AND CONCLUSIONS

1. In south Florida, mark-recovery experiments with biological stains as the marking agents demonstrated the importance of certain shallow coastal waters as nursery grounds for pink shrimp that eventually frequent the offshore Tortugas and Sanibel grounds.

2. Some shrimp from shallow coastal waters

migrated at least 150 miles before recovery on the offshore grounds.

3. The recovery patterns show that shrimp disperse considerably between release and recovery, suggesting broad migration routes. Despite such dispersion, shrimp emanating from each nursery area indicated a distinct pattern of distribution on the offshore grounds.

4. Shrimp leaving the estuaries and moving across the offshore grounds tend to move into deeper water. Although limited movement into shallower water was noted on the offshore grounds, such movement is apparently only temporary, because recoveries after long free periods were almost always from deeper water.

5. Mark-recovery data reveal that the length of time spent in the estuaries by shrimp may vary from about 2 to at least 6 months.

6. Between release in an estuary and recovery on an offshore trawling ground the minimum free time of any marked shrimp was 35 days, the maximum 331 days.

7. Shrimp available for capture on the Tortugas trawling grounds emanate from shallower waters to the north, northeast, and east of the grounds. In these directions, the Tortugas stock recruitment range extends at least as far as the south Sanibel grounds, Indian Key, Shark River, Flamingo, Bottle Key, Peterson Keys, and that portion of Hawk Channel south of Bahia Honda Key. Thus, a large portion of the estuarine nursery grounds is located within Everglades National Park. Shallows within the Tortugas grounds may also be a source of recruits to this fishery. The affinity to the Tortugas stocks of pink shrimp occurring in deep water east and south of the Florida Keys, and south, west, and northwest of the Tortugas grounds has not been established.

8. Shrimp available for capture on the south Sanibel trawling grounds emanate from shallower waters along the adjacent coast. Coastally, minimum limits of the recruitment area range from Pine Island Sound, to the north, to Indian Key, southeast of the grounds. Offshore, pink shrimp of the south Sanibel stocks occur on the northwest Sanibel grounds and on the northwestern portion of the Tortugas grounds. The relationship of the south Sanibel pink shrimp to those inhabiting deeper water west of the grounds is not known.

9. The Sanibel and Tortugas stocks overlap along the southwest coast of Florida and in the offshore water between the two trawling grounds. There is evidence that young shrimp recruited from nursery grounds as remote as northeastern Florida Bay and Pine Island Sound associate, as adults, in the area intervening between the Sanibel and Tortugas grounds. Apparently Tortugas shrimp do not migrate to the Sanibel trawling grounds, and south Sanibel shrimp seldom migrate to the Tortugas trawling grounds, or to the northwest Sanibel grounds.

10. The geographic distribution of the Tortugas and Sanibel shrimp stocks as presented here constitutes a minimum range. The absence of fishing effort in certain contiguous regions precluded recoveries and, therefore, identification of these regions as part of the range. In addition, insufficient knowledge of the migrations of larval and postlarval shrimp precludes determination of their origin, which may be beyond the region known to be frequented by the Tortugas and Sanibel shrimp stocks as juveniles and adults.

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